Chapter 5—Pollution Prevention and Source Controls

5.1 Overview

Pollution prevention techniques must, to the extent practicable, be incorporated into all site designs, especially at commercial and light industrial sites, to minimize the potential impact those activities may have on stormwater runoff quality. Preventative source controls, while more limited, must also be applied in residential development, particularly in preventing floatables (trash and debris) from entering storm sewer drainage systems.

5.2 General Pollution Prevention Design Features

Inlets must incorporate trash racks wherever practicable. Storm drain marking (e.g., stenciling) to discourage dumping must also be provided at each inlet. Regular maintenance and inspection of trash racks must be provided for in maintenance plans.

5.3 Solid Waste Containment

Proper containment of solid waste will prevent it from entering drainage systems and polluting waterways. At a minimum, apply the following pollution prevention practices:

- Trash and recycling receptacles must be provided with regular collection at all sites.
- Industrial and commercial sites must include regular street sweeping (at least annually) in their maintenance plans.
- Pet waste stations that avail bags and waste containers are recommended at all residential developments and must be provided at multiunit dwellings such as apartments, town houses and condominiums.

5.4 Roads and Parking Area Management

Roads and parking areas constitute a large portion of Rhode Island's impervious surfaces and are often directly connected to storm drain systems. Roadways and parking areas are noted contribute relatively high concentrations of a wide variety of pollutants including sediment, nutrients, metals and volatile organic compounds (VOCs) to name a few. The discussion below addresses guidance requirements related to road and parking area management:

Street sweeping: Street sweeping helps to remove sediment and debris from paved surface and reduces potential pollutant transport to waterbodies. Street sweeping may also reduce the need for maintenance of pretreatment devices, such catch basins and forebays that may precede water quality ponds. Street sweeping is a requirement for municipalities pursuant to Phase II of the RIPDES Storm Water Regulations. Interested parties should refer to these regulations for more information. Street and parking lot sweeping is recommended for private entities to reduce the need for maintenance of pretreatment devices, but is not required. Currently available street sweeping technology is not considered to provide any particular sediment removal benefit and should not be relied on for TSS removal.

Disposal of sweepings: Street sweepings are generally regulated as a hazardous waste and must be disposed of in accordance with appropriate practice and applicable regulatory standards. Interested parties should contact DEM Office of Waste Management further information.

Deicing and salt storage: Deicing and sanding operations are often necessary for safety during winter storms. At the same time, these operations leave residues that are known to create water quality problems. Use deicing chemicals and sand judiciously. Consider the information in Table 5.4-1 when selecting a deicer.

Table 5.4-1

Comparison of Environmental Effects of Common Roadway Deicers

Media	Sodium Chloride ($NaCl$)	Calcium Chloride ($CaCl_2$)	CMA ($CaMgC_2H_3O_2$)	Sand (SiO_2)
Soils	Cl complexes release heavy metals; Na can break down soil structure and decrease permeability	Ca can exchange with heavy metals, increase soil aeration and permeability	Ca and Mg can exchange with heavy metals	Gradually will accumulate on soil
Vegetation	Salt spray/splash can cause leaf scorch and browning or dieback of new plant growth up to 50 feet from road; osmotic stress can result from salt uptake; grass more tolerant than trees and woody plants		Little effect	Accumulates on and around low vegetation
Groundwater	Mobile Na and Cl ions readily reach groundwater, and concentration levels can increase in areas of low flow temporarily during spring thaws. Ca and Mg can release heavy metals from soil			No known effect
Surface Water	Can cause density stratification in small lakes having closed basins, potentially leading to anoxia in lake bottoms; often contain nitrogen, phosphorus, and trace metals as impurities, often in concentrations greater than 5 ppm		Depletes dissolved oxygen in small lakes and streams when degrading	No known effect
Aquatic Biota	Little effect in large or flowing bodies at current road salting amounts; small streams that are end points for runoff can receive harmful concentrations of Cl; Cl from NaCl generally not toxic until it reaches levels of 1,000-36,000 ppm.		Can cause oxygen depletion	Particles to stream bottoms degrade habitat

Source: Adapted from Ohrel, 2000

Sand and deicing chemicals should be stored under cover so as to prevent their exposure to stormwater. Table 5.4-2 provides recommendations appropriate storage and use of deicers.

Storage of these materials may be regulated as an industrial activity. Interested parties should contact DEM's Storm Water Program in the Office of Water Resources for further information.

Table 5-2. Recommendations to Reduce Deicer Impacts

Activity	Recommendation
Storage	• Salt storage piles should be completely covered, ideally by a roof and, at a minimum, by a weighted tarp, and stored on impervious surfaces. • Runoff should be contained in appropriate areas. • Spills should be cleaned up after loading operations. The material may be directed to a sand pile or returned to salt piles. • Avoid storage in drinking water supply areas, water supply aquifer recharge areas, and public wellhead protection areas.
Application	• Application rate should be tailored to road conditions (i.e., high versus low volume roads) • Trucks should be equipped with sensors that automatically control the deicer spread rate • Drivers and handlers of salt and other deicers should receive training to improve efficiency, reduce losses, and raise awareness of environmental impacts.
Other	• Identify ecosystems such as wetlands that may be sensitive to salt. • Use calcium chloride and CMA in sensitive ecosystem areas. • To avoid over-application and excessive expense, choose deicing agents that perform most efficiently according to pavement temperature. • Monitor the deicer market for new products and technology.

Source: Adapted from Ohrel, 2000.

Snow disposal: Snow disposal is not currently a regulated activity in Rhode Island, however, the following areas should be avoided when disposing of snow:

- Storm drainage catch basins
- Storm drainage swales
- Stream or river banks that slope toward the water
- Freshwater or tidal wetlands or immediately adjacent areas
- Within 100feet of private drinking water supply wells
- Within 500 feet of public drinking water supply wells
- Public drinking water supply watershed areas.

5.5 Hazardous Materials Containment

As applicable, project proponents must provide a completed Stormwater Pollution Prevention Plan in accordance with the Rhode Island Pollution Discharge Elimination System

Regulations. At a minimum, the following practices should be incorporated as part of site design:

- Site designs must incorporate adequate indoor storage of hazardous materials as the primary method for preventing problems related to stormwater.
- Diversion through devices such as curbing and berms should be incorporated wherever stormwater has the potential to runoff into hazardous materials storage areas.
- Secondary containment must be included wherever spills might occur (e.g., fueling and hazardous materials transfer and loading areas). Oil/grit separators and other manufactured treatment devices may temporarily contain certain spills and contaminated stormwater. However, these devices should be used as backup for tighter containment practices.

5.6 Septic System Management

Approximately one-third of Rhode Islanders use some form of onsite wastewater disposal system (i.e., septic system, cesspool, etc.). When septic systems fail, they may become a major source of pollution to surface and groundwater. Discharge from failed systems is often carried to surface water via stormwater runoff. Some failed Stormwater management plans must discuss appropriate operation and management for all individual sewage disposal systems (ISDSs) on the project site. Use of regular inspections in accordance with the procedures of *Septic System Checkup: The Rhode Island Manual* for Inspections is recommended.

5.7 Lawn, Garden, and Landscape Management

Lawns are a significant feature of urban landscapes. Estimates of turf and lawn coverage in the United States are as high as 30 million acres, which, if lawns were classified as a crop, would rank as the fifth largest in the country after corn, soybeans, wheat, and hay (Swann and Schueler, 2000). This large area of managed landscape has the potential to contribute to urban runoff pollution due to overfertilization, overwatering, overapplication of pesticides, and direct disposal of lawn clippings, leaves, and trimmings. Also, erosion from bare patches of poorly managed lawns contribute sediment to watercourses, and disposal of lawn clippings in landfills can reduce the capacity of these facilities to handle other types of waste.

The following standards for grounds management must be incorporated into stormwater management plans:

Lawn conversion: Grasses require more water and attention that alternative groundcovers, flowers, shrubs and trees. Alternatives are especially recommended for problem areas such as lawn edges, frost pockets, shady spots, steep slopes and soggy areas. Vegetation that is best suited to the local conditions should be chosen instead of turf.

Soil building: Grounds operation and maintenance should incorporate soil evaluation every 1 to 3 years to determine suitability for supporting a lawn and to determine how to optimize growing conditions. Consider testing soil characteristics such as pH, fertility, compaction, texture, and earthworm content.

Grass selection: Grass seed is available in a wide range of cultivated varieties, so homeowners, landscapers and grounds managers are able to choose the grass type that grows well in their particular climate, matches site conditions, and is consistent with the property owner's desired level of maintenance. When choosing ground cover, consideration should be given to seasonal variations in rainfall and temperature. Table 5.7-1 lists turfgrass types and their level of tolerance to drought:

Table 5.7-1
Drought Tolerance of Turfgrass Types

Turfgrass Type	Drought Tolerance
Fine-leaved Fescues	High
Tall Fescue	
Kentucky Bluegrass	
Perennial Ryegrass	
Bentgrasses	Low

Mowing and thatch management To prevent insects and weed problems, property owners should mow high, mow frequently, and keep mower blades sharp. Lawns should not be cut shorter than 2 to 3 inches because weeds can grow more easily in short grasses. Grass can be cut lower in the spring and fall to stimulate root growth, but not shorter than 1 ½ inches.

Minimize fertilization

If fertilizing is desired, consider the following points:

- Most lawns require little or no fertilizer to remain healthy. Fertilize no more than twice a year—once in May-June and once in September-October.
- Fertilizers are rated on their labeling by three numbers (e.g., 10-10-10 or 12-4-8). The percentage of nitrogen is the first number. Fertilize at a rate of no more than ½ pound per 1000 square feet, which can be determined by dividing 50 by the percentage of nitrogen in the fertilizer.
- Apply fertilizer carefully so as to avoid spreading on nongrowing surfaces (e.g., walkways, patios, etc).
- To encourage more complete uptake, use slow-release fertilizers that is those that contain 50 percent or more water-insoluble nitrogen (WIN).
- Grass blades retain 30-40 percent of fertilizer applied. Reduce fertilizer applications by 30 percent or eliminate the spring feeding by leaving clippings on the lawn.
- Fertilizer should not be applied when rain is expected. Not only does the rain decrease fertilizer effectiveness, it also increases the risk of surface and ground water contamination.

Weed and pest management: A property owner must decide how many weeds can be tolerated before action is taken to eradicate them. To the extent practicable weeds should be dug or pulled out. If patches of weeds are present, they can be covered for a few days with a black plastic sheet, a technique called solarization. Solarization kills the weeds while leaving the grass intact. If weeds blanket a large enough area, the patch can be covered with clear plastic for several weeks, effectively "cooking" the weeds and their seeds. The bare area left behind after weeding should be reseeded to prevent weeds from growing back. As a last resort, homeowners can use chemical herbicides can be used to spot-treat weeds.

Pest management: Effective pest management begins with maintenance of a healthy, vigorous lawn that is naturally disease resistant. Property owners should monitor plants for obvious damage and should check for the presence of pest organisms. Learn to distinguish beneficial insects and arachnids, such as green lacewings, ladybugs, and most spiders, from ones that will damage plants. When damage is detected or when harmful organisms are present, property owners should determine the level of damage the plant is able to tolerate. No action should be taken if the plant can maintain growth and fertility. If controls are needed, there is an arsenal of low-impact pest management controls and practices to choose from, including the following:

- Visible insects can be removed by hand (with gloves or tweezers) and placed in soapy water or vegetable oil. Alternatively, insects can be sprayed off the plant with water or in some cases vacuumed off of larger plants.
- Store-bought traps, such as species-specific, pheromone-based traps or colored sticky cards, can be used.
- Sprinkling the ground surface with abrasive diatomaceous earth can prevent infestations by soft-bodied insects and slugs. Slugs also can be trapped in small cups filled with beer that are set in the ground so the slugs can get in easily.
- In cases where microscopic parasites, such as bacteria and fungi, are causing damage to plants, the affected plant material can be removed and disposed of. (Pruning equipment should be disinfected with bleach to prevent spreading the disease organism.)
- Small mammals and birds can be excluded using fences, netting, tree trunk guards, and, as a last resort, trapping. (In some areas trapping is illegal. Property owners should check local codes if this type of action is desired.)
- Property owners can promote beneficial organisms, such as bats, birds, green lacewings, ladybugs, praying mantis, ground beetles, parasitic nematodes, trichogramma wasps, seedhead weevils, and spiders, that prey on detrimental pest species. These desirable organisms can be introduced directly or can be attracted to the area by providing food and/or habitat.

If chemical pesticides are used, property owners should try to select the least toxic, water soluble, and volatile pesticides possible. All selected pesticides should be screened for their potential to harm water resources. Organophosphate pesticides, such as diazinon and chlorpyrifos, are popular because they target a broad range of pests and they are less expensive than newer, less toxic pesticides. Organophosphates rank among the worst killers of wildlife, however, and they often pose the greatest health risk. Synthetic pyrethroids are more selective and typically much less toxic than organophosphates, yet they can harm beneficial insects. When possible, pesticides that pose less risk to human health and the environment should be chosen. A list of popular pesticides, along with their uses, their toxicity to humans and wildlife, EPA's toxicity rating, and alternatives to the listed chemicals is available from The Audubon Guide to Home Pesticides, which is available online.

Sensible irrigation: Most New England lawns will survive without irrigation. Grasses will normally go dormant in warm, dry periods (June-September) and resume growth when moister is more plentiful. However, if watering is desired, consider the following points:

- Established lawns need no more than one inch of water per week (including precipitation) to prevent dormancy in dry periods. Watering at this rate should wet soil to approximately 4-6 inches and will encourage analogous root growth.
- If possible use timers to water before 9:00 a.m., preferable in the early morning, to avoid evaporative loss.
- Use drought resistant grasses (see "grass selection," above) and cut grass at 2-3 inches to encourage deeper rooting and heartier lawns.

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Chapter Six –Innovative/Emerging Technologies

Stormwater treatment practices are continually evolving in response to advances in treatment technology, availability and affordability of new technology, and recognition of new treatment needs. The following section provides examples of recently developed innovative and emerging technologies for stormwater treatment. Emerging technologies generally may be good candidates for stormwater retrofits and where land is unavailable for larger systems. This section describes recommended criteria for evaluating new or emerging stormwater treatment technologies and examples of currently available technologies.

6.1 Examples of Innovative and Emerging Technologies

Most innovative or emerging technologies are proprietary devices developed by various manufacturers and vendors. System designs vary considerably, although most currently available technologies generally can be grouped into one of the following categories:

- ***Hydrodynamic Separators:*** This group of stormwater treatment technologies is designed to remove large particle total suspended solids and large oil droplets. They consist primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing stormwater drainage systems (Washington, 2000). The most common mechanism used in these devices is vortex-enhanced sedimentation, also called swirl concentration. In these structures, often called swirl concentrators, stormwater enters as tangential inlet flow into the side of the cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater (EPA, 2002). Some devices also have compartments or chambers to trap oil and other floatables.

  Although swirl concentration is the technology employed by most hydrodynamic separators, some systems use circular screening systems or engineered cylindrical sedimentation. Circular screened systems use a combination of screens, baffles, and inlet and outlet structures to remove debris, large particle total suspended solids, and large oil droplets. Sorbents can also be added to these structures to increase removal efficiency (Washington, 2000). Structures using engineered cylindrical sedimentation use an arrangement of internal baffles and an oil and sediment storage compartment.

- ***Media Filters:*** In this type of treatment practice, media is placed within filter cartridges that are typically enclosed in concrete vaults. Stormwater is passed through the media, which traps particulates and/or soluble pollutants. Various materials can be used as filter media including pleated fabric, activated charcoal, perlite, amended sand and perlite mixes, and zeolite. Selection of filter media is a function of the pollutants targeted for removal. Pretreatment prior to the filter media is typically necessary for stormwater with high total suspended solids, hydrocarbon, and debris loadings that may cause clogging and premature filter failure (Washington, 2000).

- ***Underground Infiltration Systems:*** Various types of underground infiltration structures, such as premanufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications. Similar to traditional infiltration trenches and basins, these systems are designed to capture, temporarily store, and infiltrate the design water quality volume over several days. Performance of underground infiltration structures varies by manufacturer and system design. These systems are currently considered secondary treatment practices due to limited field performance data, although pollutant removal efficiency is anticipated to be similar to that of infiltration trenches and basins.

6.2 Criteria for Evaluating New Practices

New and emerging stormwater treatment practices may be acceptable if they can be demonstrated to remove 100 percent of 70 ug particles from the water quality volume during the flow generated by the 2-year, 24-hour storm. This may generated using field verification or standard engineering practices.

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Chapter Seven – Hydrologic Sizing Criteria for Stormwater Treatment Practices

7.1 Introduction

This chapter presents a recommended approach for sizing stormwater treatment practices in the State of Rhode Island. Although the primary focus of this manual is on stormwater quality, the management of stormwater quantity is an important related concern especially as it will define the hydraulic capacity of any water quality improvement. Therefore, the sizing criteria in this chapter are designed to achieve both water quality and quantity control objectives. The recommended sizing criteria have been adapted from the Center for Watershed Protection's Unified Sizing Criteria, which is one of the more comprehensive approaches for sizing stormwater treatment practices developed to date. This approach has been implemented in several other states including Connecticut, Maryland, New York, Vermont, and Georgia.

The sizing approach described in this chapter is intended to manage storm flows and associated water quality and quantity impacts for storms ranging in magnitude from the small, frequent storms that are responsible for a majority of the annual runoff volume and pollutant loads to the large, infrequent events which are responsible for nuisance and catastrophic flooding. Stormwater treatment practices should be designed to accomplish the following primary objectives:

- Pollutant reduction.
- Runoff volume reduction and groundwater recharge.
- Peak flow control and stream channel protection.

The following sections of this chapter describe criteria and methods for calculating hydraulic loads to stormwater treatment practices to meet these objectives. These criteria are intended to be consistent with local subdivision and planning/zoning ordinances of most municipalities throughout the state, particularly regarding peak flow control requirements. Some differences may exist between the criteria presented in this chapter and local requirements. Local requirements should be consulted in addition to these criteria, however, the criteria presented in this chapter are recommended where local regulations are less stringent. Regardless, the most stringent requirements should be utilized.

7.2 Criteria Applicability

The design criteria presented in this chapter are generally applicable to the following types of new development and redevelopment projects, including phased developments:

- Any development resulting in the disturbance of greater than or equal to one acre of land
- Residential development consisting of 5 or more dwelling units
- Residential development consisting of <5 dwelling units involving construction of a new road or reconstruction of an existing road

- Residential development consisting of <5 dwelling units where imperviousness of the site after construction exceeds 30%
- Stormwater discharge to sensitive wetlands/watercourses
- New stormwater discharges located less than 500 feet from coastal wetlands
- Land uses or activities with potential for higher pollutant loadings (see Table 7.5.1-2), excluding the groundwater recharge criterion
- Industrial and commercial development projects which result in 10,000 sq. ft. or greater of impervious surface
- New highway, road, and street construction
- Modifications to existing storm drainage systems.

These criteria apply to whole projects. For example, dividing a project into phases such that one or more of its phases would fall below these criteria would still meet these criteria if the entire project meets the criteria.

These and other types of projects not listed above, such as single-family residential development, are encouraged to incorporate alternative site design, low impact development practices, and source controls to reduce imperviousness, runoff volumes, and stormwater pollutant sources, which are discussed in chapters 4 and 5.

Some of the sizing criteria presented in this chapter may not be practical to meet due to space limitations, soil conditions, and other site constraints which are common in redevelopment or retrofit applications. Treatment practices sized for smaller treatment volumes/flows or exemptions from certain criteria may be appropriate in these situations, at the discretion of the review authority. Conditions where the recommended sizing criteria may not be applicable are identified in the following sections.

7.3 Criteria Summary

Table 7.3-1 summarizes the hydrologic sizing criteria for stormwater treatment practices in Rhode Island. As indicated in Table 7.3-1, the sizing criteria are based on stormwater runoff generated by 24-hour duration storms of various return frequencies (i.e., design storms). Table 7.3-2 lists 24-hour design rainfall depths for the State of Rhode Island that has been divided into three regions: (1) the northern section consisting of the cities and towns in Providence County, (2) the eastern section of Rhode Island consists of the cities and towns in Newport and Bristol Counties, and (3) the southern section consisting of the cities and towns in Kent and Washington Counties. The rationale for and application of these criteria are described in the following sections.

Table 7.3-1

Summary of Stormwater Treatment Practice Sizing Criteria

Sizing Criteria	Description	Post-Development Storm Magnitude
Pollutant Reduction	***Water Quality Volume (WQV)*** Volume of runoff generated by one inch of rainfall on the site WQV = (1")(A)/12 WQV = water quality volume (ac-ft) A = site impervious area in acres ***Water Quality Flow (WQF)*** Peak flow associated with the water quality volume calculated using the NRCS Graphical Peak Discharge Method	First one inch of rainfall
Groundwater Recharge	***Groundwater Recharge Volume (GRV)*** Maintain pre-development annual groundwater recharge volume to the maximum extent practicable through the use of infiltration measures	
Peak Flow Control	***Conveyance Protection*** Design the conveyance system leading to, from, and through stormwater management facilities based on the 10-year, 24-hour storm or a storm. ***Peak Runoff Attenuation*** Control the post-development peak discharge rates from the 2, 10-, 25-, and 100-year storms to the corresponding pre-development peak discharge rates. ***Emergency Outlet Sizing*** Size the emergency outlet to safely pass the post-development peak runoff from, at a minimum, the 100-year storm in a controlled manner without eroding the outlet works and downstream drainages.	10-year, 24-hour rainfall 2, 10-, 25-, and 100-year 24-hour rainfall 100-year, 24-hour rainfall

Consult local regulations for additional criteria. The above criteria are recommended where local regulations are less stringent.

Table 7.3-2
Design Rainfall Amounts for Rhode Island

Section	24-Hour Rainfall Amount (inches)						
	1-Year	2-Year	5-Year	10-Year	25-year	50-Year	100-Year
Northern	2.7	3.3	4.2	4.8	5.6	6.2	7.0
Eastern	2.7	3.4	4.3	4.9	5.7	6.3	7.1
Southern	2.7	3.4	4.4	5.0	5.8	6.4	7.2

Source: U.S. Department of Commerce and Weather Bureau, Technical Paper No. 40, May 1961; Exhibit 2-3.1 CT-RI, April 1982.

7.4 Pollutant Reduction

The pollutant reduction criterion is designed to improve the water quality of stormwater discharges by treating a prescribed water quality volume or associated peak flow, referred to as the water quality flow. The following paragraphs describe how to calculate the water quality volumes and flows that will be used to size storm water treatment practices.

7.4.1 Water Quality Volume (WQV)

The water quality volume (WQV) is the amount of stormwater runoff from any given storm that should be captured and treated in order to remove a significant fraction of stormwater pollutants on an average annual basis. The recommended WQV, which results in the capture and treatment of the entire runoff volume for 90 percent of the average annual storm events, is equivalent to the runoff associated with the first 1.2 inches of rainfall over the impervious surface. The WQV is calculated using the following equation:

$$WQV = \frac{(1'')(A)}{12}$$

where: $WQV =$ water quality volume (ac-ft)
$A =$ site impervious area in acres

- Impervious area should be measured from the site plan and include all impermeable surfaces that are directly or indirectly connected to the stormwater treatment practice such as paved and gravel roads, rooftops, driveways, parking lots, sidewalks, pools, patios and decks. In the absence of site-specific information, impervious cover may be estimated based on average impervious coverage values for various cover descriptions as listed in Technical Release 55 – Urban Hydrology for Small Watersheds, 2nd Edition.

- The WQV should be treated by an acceptable stormwater treatment practice or group of practices described in this manual. The WQV should be used for the design of the stormwater treatment practices described in this manual.

The above approach is similar to water quality sizing criteria that have been adopted elsewhere in the United States for the design of stormwater treatment practices. These criteria are intended to remove the majority of pollutants in stormwater runoff at a reasonable cost by capturing and treating runoff from small, frequent storm events that account for a majority of the annual pollutant load, while bypassing larger, infrequent storm events that account for a small percentage of the annual pollutant load. This approach is based on the "first flush" concept, which assumes that the majority of pollutants in urban stormwater runoff are contained in the first half-inch to one-inch of runoff primarily due to pollutant washoff during the first portion of a storm event. Early studies in Florida determined that the first flush generally carries 90 percent of the pollution from a storm (Novotny, 1995). As a result, treatment of the first half-inch of runoff was adopted as a water quality volume sizing criterion requirement throughout much of the United States. More recent research has shown that pollutant removal achieved using the half-inch rule drops off considerably as site imperviousness increases.

A number of alternative water quality sizing methods were developed to achieve higher pollutant removals for a wider range of site imperviousness. One of the more common methods is known as the "90 Percent Rule," in which the water quality volume is equal to the storage required to capture and treat 90 percent of the annual runoff events (approximately 90% of the annual runoff pollutant load) based on analysis of historical precipitation records. The specific rainfall event captured is the storm event that is less than or equal to 90 percent of all 24-hour storms on an average annual basis. In the northeastern U.S., the 90 percent rainfall event is equal to approximately 1.2 inches. As indicated by TR-55, 1.2 inches of rain will generate 1 inch of runoff from an impervious surface, which is equal to the water quality volume.

7.4.2 Water Quality Flow (WQF)

The water quality flow (WQF) is the peak flow rate associated with the water quality design storm or WQV. Although most of the stormwater treatment practices in this manual should be sized based on WQV, some treatment practices such as proprietary treatment devices (designed to treat higher flow rates, thereby requiring less water quality storage volume) are more appropriately designed based on peak flow rate. In this approach, a stormwater treatment facility must have a flow rate capacity equal to or greater than the WQF in order to treat the entire water quality volume (Adams, 1998). In addition, flow diversion structures for off-line stormwater treatment practices can also be designed to bypass flows greater than the WQF.

The WQF should be calculated using the WQV described above and the NRCS hydrograph methods. The procedure is based on the approach described in Claytor and Schueler, 1996 and is summarized in <u>Appendix B</u>. <u>Appendix B</u> also contains design guidance for flow diversion structures.

The use of NRCS hydrograph methods in conjunction with the water quality volume for computing the peak flow associated with the water quality design storm is preferable to both traditional SCS Methods and the Rational Equation, both of which have been widely used for peak runoff calculations and drainage design. The traditional SCS TR-55 methods are valuable for estimating peak discharge rates for large storms (i.e., greater than 2 inches), but can significantly over- or underestimate runoff from small storm events (Claytor and Schueler, 1996). Similarly, the Rational Equation may be appropriate for estimating peak flows for small urbanized drainage areas with short times of concentration, but does not estimate runoff volume and is based on many restrictive assumptions regarding the intensity, duration, and aerial coverage of precipitation

7.5 Groundwater Recharge

This standard is designed to reduce stormwater runoff volumes and maintain groundwater recharge rates to pre-development levels as practicable.

7.5.1 Groundwater Recharge Volume (GRV)

Description

The groundwater recharge standard is intended to maintain pre-development annual groundwater recharge volumes by capturing and infiltrating stormwater runoff. The objective of the groundwater recharge standard is to protect water table levels, stream baseflow, and wetland moisture levels. Infiltrating stormwater also provides significant water quality benefits such as reduction of pathogens, nutrients and metals. Maintaining pre-development groundwater recharge conditions can also reduce the volume requirements dictated by the other sizing criteria (i.e., water quality, channel protection, and peak flow control) and the overall size and cost of stormwater treatment practices.

The groundwater recharge volume (GRV) is the post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual pre-development groundwater recharge. The GRV is determined as a function of annual pre-development recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site. Several approaches can be used to calculate the GRV:

- ***Hydrologic Soil Group Approach:*** This method was first developed and adopted by the state of Massachusetts, and has since been implemented in several other states including Maryland and Vermont. This approach involves determining the average annual predevelopment recharge volume at a site based on hydrologic soil groups (HSG) as determined from the Natural Resource Conservation Service (NRCS) County Soil Surveys (MADEP, 1997). Based on this approach, the GRV can be calculated as follows:

$$GRV = \frac{(F)(A)(I)}{12}$$

where: $GRV =$ groundwater recharge volume (ac-ft)
$F =$ recharge factor (inches), see Table 7-4 below
$A =$ site area (acres)

I = post-development site imperviousness (decimal) for new development projects or the net increase in site imperviousness for re-development projects

Table 7.5.1-1

Groundwater Recharge Factors

Hydrologic Soil Group	Recharge Factor (F)
A	0.41 inches
B	0.27 inches
C	0.14 inches
D	0.7 inches (waived)

Source: MADEP, 1997.

- ***Other Methods:*** Predevelopment recharge values and the required GRV can also be determined using the results of on-site soil evaluations or other geologic information provided that information sources and methods are clearly documented.

Meeting the recharge requirement can be accomplished through direct infiltration practices (e.g., drywells, infiltration trenches, etc.) or recharged via techniques such as disconnection of rooftop runoff and grading. Stormwater ponds and wetlands generally are not suitable practices for groundwater. Furthermore, detention devices that temporarily detain runoff and then release it slowly over time cannot be used to satisfy the groundwater recharge requirement. When designing infiltration practices, a factor of safety should be used to account for potential compaction of soils by construction equipment, which can significantly reduce soil infiltration capacity and groundwater recharge. See the design sections of this manual for guidance on the design and construction of infiltration practices to reduce this potential.

The GRV is considered as part of the total water quality volume (WQV) and therefore can be subtracted from the WQV, provided that the proposed infiltration measures are capable of infiltrating the required recharge volume. Reducing the WQV (and consequently the size and cost of stormwater treatment) is an additional incentive for meeting the groundwater recharge criterion. Additionally, both WQV and GRV are a function of site imperviousness, providing further incentive to minimize site impervious cover.

There are several instances where the groundwater recharge criterion should be waived to protect against contamination of drinking water supplies and mobilization of existing subsurface contamination. Infiltration of stormwater is not recommended under the following site conditions:

- ***Land Uses or Activities with Potential for Higher Pollutant Loads:*** Infiltration of stormwater from these land uses or activities (Table 7.5.1-2), also referred to as stormwater "hotspots", can contaminate public and private groundwater supplies. Infiltration of stormwater from these land uses or activities may be allowed by the review authority with appropriate pretreatment. Pretreatment could consist of one or a combination of the primary or secondary treatment practices described in this manual provided that the treatment practice is designed to remove the stormwater contaminants of concern.

- ***Subsurface Contamination:*** Infiltration of stormwater in areas with soil or groundwater contamination such as brownfield sites and urban redevelopment areas can mobilize contaminants.

- ***Groundwater Supply Areas:*** Infiltration of stormwater can potentially contaminate groundwater drinking water supplies in public drinking water aquifer recharge areas and wellhead protection areas.

Table 7.5.1-2

Land Uses or Activities with Potential for Higher Pollutant Loads

Land Use/Activities	
Industrial facilities subject to the DEP Industrial Stormwater General Permit or the U.S. EPA National Pollution Discharge Elimination System (NPDES) Stormwater Permit Program[1]	Road salt storage facilities (if exposed to rainfall)
Vehicle salvage yards and recycling facilities	Commercial nurseries
Vehicle fueling facilities (gas stations and other facilities with on-site vehicle fueling)	Flat metal rooftops of industrial facilities
Vehicle service, maintenance, and equipment cleaning facilities	Facilities with outdoor storage and loading/unloading of hazardous substances or materials, regardless of the primary land use of the facility or development
Fleet storage areas (cars, buses, trucks, public works)	Facilities subject to chemical inventory reporting under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA), if materials or containers are exposed to rainfall
Commercial parking lots with high intensity use (shopping malls, fast food restaurants, convenience stores, supermarkets, etc.)	Marinas (service and maintenance)
Public works storage areas	Other land uses and activities as designated by the review authority

[1]Stormwater pollution prevention plans are required for these facilities. Pollution prevention and source controls are recommended for the other land uses and activities listed above.

7.6 Peak Flow Control

Peak flow control criteria are intended to address increases in the frequency and magnitude of a range of potential flood conditions resulting from development. These include relatively frequent events that cause channel erosion, larger events that result in bank full and overbank flooding, and extreme floods. The following sections describe sizing criteria for controlling peak flows, as well as for designing stormwater conveyance and emergency outlet structures. Natural Resource Conservation Service (NRCS) hydrograph methods such as TR-55 or TR-20 should be used to compute the required peak flow rates for the criteria described below.

7.6.1 Conveyance Protection

The conveyance systems to, from, and through stormwater management facilities should be designed based on the peak discharge rate for at least the 10-year, 24-hour storm. This criterion is designed to prevent erosive flows within internal and external conveyance systems associated with stormwater treatment practices such as channels, ditches, berms, overflow channels, and outfalls. The local review authority may require the use of larger magnitude design storms for conveyance systems associated with stormwater treatment practices.

7.6.2 Peak Runoff Attenuation

The peak runoff attenuation criterion is designed to address increases in the frequency and magnitude of flooding caused by development. This criterion is intended to control a range of flood conditions, from events that just exceed the bank full capacity of the stream channel to catastrophic flooding associated with extremely large events. Other objectives include maintaining the boundaries of the pre-development 100-year floodplain and protecting the physical integrity of stormwater management facilities.

The recommended peak runoff attenuation criterion in Rhode Island includes control of post-development peak discharge rates from the 2-year, 10-year, 25-year, and 100-year frequency storms to the corresponding pre-development peak discharge rates. The local review authority may also require peak runoff attenuation for additional design storms such as the 1-year, 2-year, 5-year and 50-year events. The peak runoff attenuation criterion for sites that discharge to a large river, lake, estuary, or tidal waters where the development area is less than 5% of the watershed area upstream of the development site.

Peak runoff control criteria are typically applied at the immediate downstream boundary of a project area. However, since stormwater management facilities may change the timing of the post-development hydrograph, multiple stormwater treatment practices or detention facilities in a watershed may result in unexpected increases in peak flows at critical downstream locations such as road culverts and areas prone to flooding. This effect is most pronounced for detention structures in the middle to lower third of a watershed. The local review authority may require a downstream analysis to identify potential detrimental effects of proposed stormwater treatment practices and detention facilities on downstream areas.

The downstream analysis should include the following elements:

- Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule").

- Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies.

- The analysis should use an appropriate hydrograph routing method, such as TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations.

The ultimate objective of this analysis is to ensure that proposed projects do not increase post-development peak flows and velocities at critical downstream locations in the watershed. Increases in flow rates and velocities at these locations should be limited to less than 5 percent of the pre-developed condition (NYDEC, 2001) and should not exceed freeboard clearances or allowable velocities.

7.6.3 Emergency Outlet Sizing

The emergency outlets of stormwater management facilities should be designed to safely pass the peak discharge rate associated with the 100-year storm or larger. The emergency outlet should be able to pass the 100-year peak runoff rate, at a minimum, in a controlled manner, without eroding outfalls or downstream conveyances. Emergency outlets constructed in natural ground are generally preferable to constructed embankments. This criterion is applicable to all stormwater management facilities that employ an emergency outlet.

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Chapter Eight – Selecting Stormwater Treatment Practices

No single stormwater treatment practice is appropriate for every site and condition. The applicability of individual practices varies depending upon both relatively simple physical constraints, as well as more complicated siting and treatment issues. This chapter addresses criteria to consider when selecting stormwater treatment practices for a particular site.

8.1 Stormwater Management Hierarchy

Certain practices are preferred over others. The list below is the Rhode Island hierarchy in declining order of preference:

1. Avoidance and minimization—Whenever possible stormwater should be controlled by limiting extent and construction of impervious surfaces and minimizing site disturbance. Discussion of appropriate practices can be found in chapter four "Nonstructural and Small-Scale Upland Management." Also, sources of pollution (e.g., hazardous materials) should be kept out of the stormwater flow path (e.g., indoors) both during and after site development.
2. Abstraction, recharge and infiltration—Runoff must be managed through recharge and infiltration in accordance with the required groundwater recharge volume (refer to chapter seven "Hydrologic Analysis." Abstraction, recharge and infiltration should always be applied as close to the source of runoff as possible. This is desirable from both the standpoint of treatment and cost effectiveness. Treatment practices that incorporate abstraction, recharge and infiltration are discussed in chapter four "Nonstructural and Small-Scale Upland Management."
3. End-of-pipe treatment—End-of-pipe treatment is the least preferred management strategy. End-of-pipe practices typically discharge to waters or conveyances (e.g., storm sewers), but have a finite capacity to treat pollutants and may provide less water quality than desirable. End-of-pipe practices also provide runoff the least opportunity for groundwater recharge and evapotranspiration.

   Notwithstanding, end-of-pipe practices should be used primarily to treat runoff from hotspot land uses and to manage runoff volumes in excess of the WQV. Some industrial and commercial uses are anticipated to generate unusually high levels of pollutants, which should not be treated by nonstructural or small-scale upland BMPs due to groundwater contamination concerns. Some examples include gas stations and landfills. Runoff from these industrial and commercial uses must be treated using appropriate end-of-pipe BMPs and source reduction techniques. In addition, these uses typically require a RIPDES permit and must incorporate a stormwater management plan in accordance with the permit.

Project proponents should note that while cost may be used as a factor in choosing between equal practices, it is not be accepted as a reason to reduce level of treatment.

8.3 Land Use Factors

Land use, both current and potential future use, should be considered when selecting stormwater treatment practices. Some practices are more "neighbor friendly" than others. Other practices are more land intensive and may be less desirable where space is at a premium. The following land use factors should be considered when selecting stormwater treatment practices.

Rural

Rural areas are typically characterized by low-density development (i.e., few neighbors) and relatively large amounts of available space. Areas of open water, which may raise concerns of mosquitoes, and stormwater treatment practices with larger area demands may be easier to locate with appropriate buffers in rural areas. Additionally, typical stormwater pollutants from rural areas include sediments and nutrients, which can be effectively managed by most stormwater treatment practices. As a result, most treatment practices are suitable for rural areas.

Residential

Medium- to high-density residential areas typically have limited space and higher property values compared to rural undeveloped areas. Also, treatment practices in these areas are likely to be located in close proximity to residences. Public safety and nuisance insects are common concerns for treatment practices in residential areas. Stormwater treatment practices with large land requirements or open pools of water may be less desirable in these areas. In some situations, stormwater ponds or other open water practices may be incorporated into the landscape as natural amenities to provide habitat, recreation, and aesthetic value. All treatment practices should be designed and operated in a manner that discourages mosquito breading. Refer to … for more information

Roads and Highways

Roads and highways typically generate high stormwater pollutant loads due to vehicle traffic and winter deicing activities. Sediments, metals, chlorides, and hydrocarbons are the primary pollutants associated with roads and highways. Nitrogen from vehicle exhausts and bacteria are also commonly present in road and highway runoff. As a result, treatment trains will need to be used to adequately address all of the water quality impacts associated with this land use. In addition, open water and deep pools can also be a safety issue near roads and highways.

Commercial and Industrial Development

Commercial and industrial areas often have more intensive traffic, increased risk of spills, and exposure of materials to precipitation. Pollutants associated with these land uses can vary significantly depending on the nature of activities at each site, although traffic-related pollutants such as sediments, metals, and hydrocarbons are commonly present in runoff from most commercial and industrial sites.

Ultra-Urban Sites
Ultra-urban sites are the most restrictive in terms of treatment practice selection. These sites are characterized as having little available space or land area, high population density, and a wide range of potential pollutants.

8.5 Physical/Site Feasibility Factors

Physical site constraints may also affect the feasibility, cost and effectiveness of treatment practices. Five primary physical siting factors in include:

- Infiltration capacity.
- Seasonally high groundwater (water table).
- Drainage area.
- Slope.
- Required hydraulic head.

These factors are discussed in general terms in the following paragraphs. Chapter eleven contains additional information on physical feasibility and siting considerations for individual treatment practices.

Infiltration Capacity
Infiltration practices are highly dependent on the infiltration capacity of the underlying soils. Low soil infiltration capacity requires structures with larger infiltration surface area and storage capacity to account for slower infiltration rates. Higher soil infiltration rates allow for smaller infiltration structures. Accurate field measurements of infiltration rates are critical for the successful design and implementation of stormwater treatment practices that rely on infiltration of stormwater to underlying soils.

Water Table
An elevated water table poses several design issues. Loss of storage and retention capacity in unlined treatment structures is a primary concern. If seasonally high groundwater exists above the bottom of an unlined pond or basin, groundwater will drain into the structure and fill or displace volume that may have been intended for retention. If a treatment practice is constructed below the seasonally high water table, the loss of storage capacity should be accounted for in the design. Underdrains should be considered.

An elevated water table may be advantageous where a permanent pool of water is desired. However, lack of separation between the bottom of a treatment structure and the water table may result in inadequate pollutant attenuation and treatment. The potential for groundwater pollution due to stormwater infiltration is an important consideration in the design of stormwater treatment practices. Engineering controls such as impermeable liners may be required.

Potential for structures to float when installed below the water table is another critical issue. The upward buoyant force may be large enough to displace a structure, sometimes out of the ground. Engineering controls typically consist of anchors such as connecting the structure to an appropriately sized concrete pad to provide adequate ballast to offset buoyant forces.

Field determination of seasonally high groundwater is required for the successful design and implementation of most stormwater treatment practices.

Drainage Area
Treatment efficiency tends to decline with increase in drainage area and hydraulic load. Some practices may be enlarged to address this issue. Other treatment practices can accept only small hydraulic loads. Treatment trains should be applied as appropriate.

Slope
Most stormwater treatment practices are sensitive to slope. For example, swales and infiltration basins cannot be used in steep terrain. The slope of the contributing drainage area or watershed can influence erosion and sediment loads to the treatment system.

Required Head
Practices, such as stormwater filtering systems, require certain hydraulic head to push water through the system. Designers should consider hydraulic head requirements when planning for stormwater management.

8.6 Downstream Resources

While all sites should provide at least a minimum level of protection, stormwater treatment practices should be tailored not only to the conditions that exist at a particular site, but also the downstream resources that could be impacted by stormwater discharges from the site. As a result, the following downstream resources should be considered in the treatment practice selection process.

Sensitive Watercourses
Streams, brooks, and rivers that are classified by DEM as Class A, as well as their tributary watercourses and wetlands, are high quality resources that warrant a high degree of protection. Toxic pollutants such as metals and soluble organics, as well as other contaminants such as bacteria are the primary concern for these waterbodies. Sensitive cold-water fisheries, including Class B waters or managed stocked streams, could also be adversely impacted by stormwater runoff with elevated temperatures. In addition, the rate and volume of stormwater discharges from new developments are especially critical to these systems, as they could impact the flood carrying capacity of the watercourse as well as increase the potential for channel erosion.

Water Supply Aquifers
Groundwater is a major source of drinking water. In addition, groundwater is the source of dry weather flows (baseflow) in watercourses, which is critical for maintaining suitable habitat. As a result, it is important to maintain groundwater recharge, as well as to maintain a high quality recharge to groundwater in water supply aquifers and Class GA and GAA waters.

Lakes and Ponds
Lakes and ponds are especially sensitive to sediment and nutrient loadings. Excess sediments and nutrients are the cause of algal blooms in these surface waters, leading to eutrophication and degradation. These conditions often result in costly dredging and rehabilitation projects. In fresh water systems, phosphorous is typically the limiting nutrient, that is, much less phosphorous is needed compared to other nutrients such as nitrogen to create eutrophic conditions. As a result, treatment practices should focus on nutrient, particularly phosphorous, removal for stormwater discharges to lakes and ponds, and watercourses that feed lakes and ponds. Control of phosphorous is also directly related to the control of iron. Certain iron compounds such as ferric iron often have a high scavenging coefficient for metals. Thus, control of phosphorous may have ancillary benefits in the control of metals.

Surface Water Drinking Supplies
Surface waters that supply drinking water are especially susceptible to contamination by bacteria and other pathogens. Treatment practices for sites within drinking water supply watersheds should target these potential contaminants. Site designs within public water supply watersheds are encouraged to maximize absorption of pollutants by the soil and vegetation.

Estuary/Coastal
Coastal or estuary areas are more sensitive to nitrogen loadings as compared to fresh water systems. In salt water systems, nitrogen tends to be the limiting nutrient as opposed to phosphorous. Bacteria are also a concern given the sensitivity of public swimming and shellfish beds to bacterial loadings.

8.7 Maintenance Factors

Regular maintenance is needed for the successful long-term operation of any stormwater treatment practice and regulatory compliance. Failure to perform adequate maintenance can lead to reductions in pollutant removal efficiency or actually increase pollutant loadings and aggravate downstream impacts. Stormwater treatment practices should be routinely inspected and maintained following construction to ensure that the controls are in proper working condition and operating as designed. General maintenance guidelines for stormwater treatment practices are summarized below. Chapter eleven contains recommended maintenance for specific stormwater treatment practices.

General maintenance requirements for stormwater treatment practices include:

Inspections: Inspections should be performed at regular intervals to ensure proper operation of stormwater treatment practices. Inspections should be conducted at least annually, with additional inspections following large storms. Inspections should include a comprehensive visual check for evidence of the following (not all items apply to every treatment practice):

- Accumulation of sediment or debris at inlet and outlet structures
- Erosion, settlement, or slope failure

- Clogging or buildup of fines on infiltration surfaces
- Vegetative stress and appropriate water levels for emergent vegetation
- Algae growth, stagnant pools, or noxious odors
- Deterioration of pipes or conduits
- Seepage at the toe of ponds or wetlands
- Deterioration or sedimentation in downstream channels and energy dissipators
- Evidence of vandalism.

Routine Maintenance: Routine maintenance should be performed on a regular basis to maintain proper operation and aesthetics. Routine maintenance should include:

- Debris and litter removal
- Silt and sediment removal
- Terrestrial vegetation maintenance
- Aquatic vegetation maintenance
- Maintenance of mechanical components (valves, gates, access hatches, locks).

Non-routine Maintenance: Non-routine maintenance refers to corrective measures taken to repair or rehabilitate stormwater controls to proper working condition. Non-routine maintenance is performed as needed, typically in response to problems detected during routine maintenance and inspections, and can include:

- Erosion and structural repair
- Sediment removal and disposal
- Nuisance control (odors, mosquitoes, weeds, excessive litter).

Stormwater treatment practice operation and maintenance requirements are an integral part of a site stormwater management plan (see Chapter Nine). The owner of a stormwater treatment system typically maintains practices. Designers should consider and demonstrate the technical capacity, dedication of manpower and delineation of responsibility to maintain systems once they are built.

8.8 Winter Operation

In Rhode Island, the effects of winter conditions (cold temperatures, snow, ice, etc.) on stormwater treatment practice performance are important considerations. While there may be fewer runoff events during winter months, snow and ice may significantly impact the operation of some treatment practices during winter rain events and periods of snowmelt. Although this manual has been written to account for cold-weather operations, designers should be cognizant of potential impacts. The following paragraphs summarize some of these impacts.

- ***Pipe Freezing:*** Most treatment practices, with the exception of vegetative filter strips, rely on some form of inlet piping, and may also have an outlet or underdrain pipe. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the hydraulic capacity of the system, thereby limiting pollutant removal and creating the potential for flooding (Center for Watershed Protection, 1997).

- ***Ice Formation on the Permanent Pool:*** Ice cover on the permanent pool causes two problems. First, the treatment pool's volume is reduced. Second, since the permanent pool is frozen, it acts as an impermeable surface. Runoff entering an ice-covered pond can follow two possible routes, neither of which provides sufficient pollutant removal. In the first, runoff is forced under the ice, causing scouring of bottom sediments. In the second, runoff flows over the top of the ice, receiving little or no treatment. Sediment that settles on top of the ice can easily be resuspended by subsequent runoff events (Center for Watershed Protection, 1997).

- ***Reduced Biological Activity:*** Many stormwater treatment practices rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. For example, wetland systems rely on plant uptake of nutrients and the activity of microbes at the soil/root zone interface to break down pollutants. During cold temperatures (below 40°F), photosynthetic and microbial activity is sharply reduced when plants are dormant during the non-growing season, limiting these pollutant removal pathways (Center for Watershed Protection, 1997).

- ***Reduced Soil Infiltration:*** The rate of infiltration in frozen soils is limited, especially when ice lenses form (Center for Watershed Protection, 1997). This reduced infiltration significantly impacts the operation of infiltration practices and other treatment systems that rely on infiltration of stormwater into the soil.

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Chapter Nine - Developing a Site Stormwater Management Plan

Site plans are essential for assessing potential impacts from the proposed development and compliance with current state and local regulations. These plans illustrate all the proposed stormwater structures and assist the regulatory agencies in reviewing the adequacy and function of designs. Site plans must be stamped, dated, and signed by a professional licensed to practice in the State of Rhode Island. This includes Professional Land Surveyors, Registered Landscape Architects and Professional Engineers.

However, plans detailing many structural best management practices and their components such as outlet structures, detention berms, etc., must be stamped by a Professional Engineer certifying the design and function of these stormwater structures.

It is imperative that applicants submit complete and accurate site plans along with any supporting calculations for this review process. Incomplete plans only delay the review process, which in turn delays the applicant from obtaining required permits and construction start-up. The following information is provided as guidance for applicants to include on site plans. However, various regulatory programs may have differing requirements that are more or less specific depending on the proposed project. Therefore, applicants are advised to seek guidance from the state or local permitting authority to ensure minimum site plan requirements are adequately addressed.

9.1 Principal Elements

A stormwater management plan should include source controls for potential sources of stormwater runoff pollution and treatment controls for stormwater discharges. In addition, any supporting documentation, including calculations, engineering details, or reports, should be provided to illustrate the proposed development's compliance with applicable federal, state, and local regulations, and the design guidelines of this manual. Professionals (engineers, surveyors, landscape architects, etc.) must affix their seal and dated signature to all plans and documents prepared by them or under their direct supervision.

The major elements of a stormwater management plan include:

- Applicant/Site Information.
- Existing and Proposed Site Maps.
- Calculations.
- Project Narrative.
- Construction Erosion and Sedimentation Control Plan.
- Operation and Maintenance Plan.
- Other Required Permits.
- Supporting Documents and Studies.

Each of these elements is described further in the following sections.

9.2 Applicant/Site Information

The stormwater management plan should include the following information to clearly identify the applicant and site of the proposed activity:

- Applicant name, legal address, and telephone/fax numbers
- Common address and legal description of the proposed site
- Site location or locus map.

9.3 Design Drawings and Site Maps

9.3.1 General Standards

Design drawings and specifications must be prepared by a professional engineer licensed to practice in the State of Connecticut. The format of site plans and drawings should conform to the following:

- Drawings should be no larger than 24" x 36" and no smaller than 8-1/2" x 11".

- Plans and documents should **not** be pieced together or submitted with handwritten markings. Blue line prints or photocopies of original plans are acceptable.

- A scale should be used that adequately presents the detail of the proposed improvements for the project. A maximum scale of 1" = 40' is recommended, however larger scales up to 1" = 100' may be used to represent overall site development plans or for conceptual plans. Profiles and cross-sections should be prepared at a maximum scale of 1" = 4' vertical and 1"=40' horizontal.

- Design details including cross-sections, elevation views, and profiles as necessary to allow the proper depiction of the proposed controls for review and permitting and ultimately to allow the proper construction of these controls.

- Specifications, which clearly indicate the materials of construction, the specific stormwater control product designations (if applicable), the methods of installation, and reference to applicable material and construction standards.

- Plans should contain a title block that includes the project title, location, owner, assessor's map and parcel number of the subject site(s), name of preparer, sheet number, date (with revision date, if applicable), and drawing scale.

- Legend defining all symbols depicted on the plans.

- A cover sheet with a sheet index for plan sets greater than two sheets. Multiple sheets should contain either match lines or provide an overlap of 1" with information on adjoining plan sheets.

- North arrow.
- Property boundary of the entire subject property and depicting the parcels, or portions thereof, of abutting land and roadways within one hundred feet of the property boundary.
- Locus map of the site prepared at a scale of 1" = 1,000' with a north arrow. The map should adequately show the subject site relative to major roads and natural features, if any.
- The seal of a licensed professional should be affixed to all original design plans, calculations, and reports prepared by them or under their direct supervision.
- Survey plans should be prepared according to the *Minimum Standards for Surveys and Maps in Connecticut* with the class of survey represented on the plan and must be stamped by a professional land surveyor. The survey plan should depict topography at contour intervals of two feet, the referenced or assumed elevation datum, two (2) benchmarks on the site within one hundred feet of the proposed construction, the outside limits of disturbances, and any plan references.

9.3.2 Existing Site Map

The existing conditions site map is useful for reviewing the physical features present at the proposed development site prior to any alteration from land disturbance or construction. This map of predevelopment conditions should at minimum include the information listed below. Additionally, this map should have a scale no smaller than 1 inch = 100 feet with contour intervals no greater than 5 feet. Larger map scales providing greater detail will be acceptable. Individual sheets must not exceed 24 inches by 36 inches.

a) North arrow with scale.
b) Existing topography of the site.
c) Subwatersheds must be clearly delineated and numbered for reference. Within each subwatershed the following information must be clearly noted: Area in acres, runoff curve number, soil types, hydrologic class, and hydrologic condition.
d) The stormwater discharge location for each subwatershed must be identified and labeled with peak discharge rates and volumes for the required design storms.
e) Location of steep slopes, bedrock outcrops, or other significant site constraints.
f) The applicants property lines and boundaries of proposed development with bearings and distances.
g) Abutting property owners and their respective boundaries must be clearly shown along with nearby utility pole numbers and adjacent streets and intersections to facilitate identification of the proposed development.
h) All perennial and intermittent streams, wetland boundaries, surface water bodies, and areas subject to storm flows or flooding must be indicated. In addition, all coastal features (as identified in the CRMP), should be delineated where applicable.

i) The 100-year flood plain boundary with 100-year flood elevations and floodway must be clearly identified consistent with the most recent Federal Emergency Management Agency maps. This may include identifying any applicable flood velocity zones.
j) The location of existing on-site stormwater structures.
k) The location and types of easements.
l) The seasonal high groundwater table in the location of proposed stormwater structures (e.g., detention basins, infiltration trenches, vegetated swales, etc.) as established in accordance with the procedures described in Section 6 of this manual.
m) Location of any required investigative soil pits or test wells.
n) The delineation of major soil types in the vicinity of the proposed development as identified by the RI Soil Survey or qualified professional.
o) Location of private and public water supply wells within 100 feet.
p) Location of existing ISDSs abutting to and within the development site.
q) Vegetation cover type including outline of woodland cover.
r) Existing open space.
s) Any landmarks, stonewalls, fences, etc.

9.3.3 Proposed Site Map

The final site map must have all information necessary to evaluate the proposed project after the final construction phase is completed. This map must be at the same scale as the existing conditions site plan map(s) and include the following information.

a) North arrow with scale.
b) Subwatersheds must be clearly delineated and numbered for reference. Within each subwatershed the following information must be clearly noted: Area in acres, runoff curve number, soil types, hydrologic class, and hydrologic condition.
c) Location of proposed structures and individual lots. These lots must be numbered for reference.
d) Delineation of Individual Sewage Disposal Systems, public and private water supply wells, utility lines, and sub-drains.
e) Location of all existing and proposed roads, driveways, parking lots, and other impervious surfaces. The total area of all impervious surfaces within each subwatershed must be clearly marked and labeled within the subwatershed boundary.
f) All new stormwater structures (BMPs), collection and conveyance systems, and remaining portions of existing systems including points of discharge shall be clearly identified.
g) The peak discharge rate and volume of stormwater flow shall be labeled where stormwater enters and exits all BMPs. Additionally, the final discharge points labeled with peak discharge rates and volumes of stormwater flow must be shown for all subwatersheds.
h) All water channels or areas subject to storm flows into to wetlands, shoreline and coastal features, and tidal waters must be clearly identified whether on-site or in abutting off-site locations.
i) Design details of all specified stormwater structures (e.g., basins, trenches, etc.) including inlet and outlet structures.

j) Limits of vegetation clearing and overall site disturbance including delineations of lawns, open space, etc.
k) The final elevational grade of the proposed development.
l) Easements are required for installation and access of all stormwater management devices. These must be clearly identified on final plans.
m) Complete soil erosion and sediment control plans to be implemented in all construction phases along with final site stabilization plans.
n) Maintenance schedules for all stormwater structures as specified in Section 12 of this manual.

9.4 Calculations

The stormwater management plan should include calculations to demonstrate that the proposed project satisfies the stormwater management objectives and treatment practice sizing criteria described in Chapter Seven of this manual.

9.4.1 Pollutant Reduction

- ***Water Quality Volume (WQV):*** Calculate the design water quality volume (WQV) to be treated by the proposed stormwater treatment practices using the procedures described in Chapter Seven. Design calculations should demonstrate that the proposed stormwater treatment practices meet the required WQV, detention time, and other practice-specific design criteria as described in this manual.

- ***Water Quality Flow (WQF):*** Calculate the design water quality flow (WQF), which is the peak flow rate associated with the WQV. The WQF is used to size flow rate-based treatment practices (i.e., manufactured treatment systems such as catch basin inserts, media filters, and hydrodynamic structures), grass drainage channels, and flow diversion structures for off-line treatment practices. The WQF should be calculated using the procedures described in Appendix B. The peak flow rates associated with larger design storms should also be evaluated to ensure that stormwater treatment practices could safely convey large storm events while providing the minimum rates of pollutant removal established in this manual.

- ***Pollutant Loads:*** At the discretion of the review authority, estimate pollutant loads found in pre- and post-development runoff. One method to determine stormwater pollutant loads for urbanized areas is the Simple Method developed by Schueler (Metropolitan Washington Council of Governments, 1987). This method can be used to estimate stormwater pollutant loads for different land uses, but does not provide an estimate of the base flow pollutant load. However, the Simple Method may be used to calculate the pollutant load associated with storm events.

9.4.2 Groundwater Recharge

- ***Groundwater Recharge Volume (GRV):*** Calculate the required groundwater recharge volume to maintain pre-development annual groundwater recharge on the site after the site is developed. The GRV should be calculated using the procedures described in Chapter Seven. The GRV calculation should include the average annual groundwater recharge (i.e., stormwater infiltration) provided by the proposed stormwater management practices.

9.4.3 Peak Flow Control (Stormwater Quantity)

For new development projects, calculations should be provided to demonstrate that post-development peak flows do not exceed pre-development peak flows for a range of design storms. For redevelopment projects, the bank condition and sensitivity of receiving waters may justify a reduction in peak flows and runoff volume from the site. Achieving a reduction in runoff from a redevelopment project may often be feasible with proper planning and implementation of detention or infiltration practices.

A number of methods and models are available to calculate peak stormwater discharge rates, and the designer must determine the most appropriate method for the project. The following information must be submitted with all stormwater management plans:

- ***Hydrologic and Hydraulic Design Calculations:*** Calculate the pre-development and post-development peak runoff rates, volumes, and velocities at the site limits. The calculations shall be based on the following 24-hour duration design storm events to satisfy the sizing criteria described in Chapter Seven:

  - Stream Channel Protection: 2-year frequency ("over-control" of 2-year storm)
  - Conveyance Protection: 10-year frequency
  - Peak Runoff Attenuation: 10-year, 25-year, and 100-year frequency (and other design storms required by the local review authority)
  - Emergency Outlet Sizing: safely pass the 100-year frequency or larger storm.

  Provide the following information for each of the above design storms for pre-development and post-development conditions:

  - Description of the design storm frequency, intensity, and duration
  - Watershed map with locations of design points and watershed area (acres) for runoff calculations
  - Time of concentration (and associated flow paths)
  - Imperviousness of the entire site and each watershed area
  - NRCS runoff curve numbers or volumetric runoff coefficients
  - Peak runoff rates, volumes, and velocities for each watershed area
  - Hydrograph routing calculations
  - Culvert capacities
  - Infiltration rates, where applicable
  - Dam breach analysis, where applicable
  - Documentation of sources for all computation methods and field test results.

- ***Downstream Analysis:*** Improperly placed or sized detention may adversely affect downstream areas by delaying the timing of the peak flows from the site. Delayed peaks can coincide with the upstream peak flow that naturally occurs later as the discharge travels from the upper portions of the watershed. If the site is in the middle to lower third of a watershed and detention is proposed, provide calculations of existing and proposed discharges at any critical downstream points using hydrograph analysis. Critical downstream points may be currently flooded properties or roadways, for example. Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule"). The downstream analysis should be performed using the methods described in Chapter Seven.

- ***Drainage Systems and Structures:*** Provide design calculations for existing and proposed drainage systems and structures at the site. Based on the design storm for those structures, a hydrograph analysis should be used to analyze the storage and discharge for detention structures. Drainage system components should be designed according to the standards outlined in this manual, as well as other applicable local standards or requirements.

9.5 Project Narrative

Projects that require a stormwater management plan must include documentation that adequately describes the proposed improvements or alterations to the site. In particular, it is necessary to describe any alterations to surface waters, including wetlands and waterways, removal of vegetation, and earth moving operations. The project scope and objective must identify, in summary, the potential water quality impacts to receiving waters during construction and the post-construction water quality and quantity impacts that may occur as a result of the intended use(s) of the property.

In describing the project, alternative designs or construction methods should be evaluated to address the goal of impact minimization through the use of site design practices such as providing "green" parking areas, and preserving natural buffers or open spaces. The purpose of evaluating project alternatives is to achieve a final design that allows an appropriate, legal use of the property while minimizing impacts to surface water quality caused by stormwater runoff.

The project narrative should consist of:

- ***Project Description and Purpose:*** Provide a general description of the project in adequate detail such that reviewers will have a sense of the proposed project and potential impacts. This section should describe existing and proposed conditions, including:

  - Natural and manmade features at the site including, at a minimum, wetlands, watercourses, floodplains, and development (roads, buildings, and other structures).
  - Site topography, drainage patterns, flow paths, and ground cover.

- Impervious area and runoff coefficient.
- Site soils as defined by USDA soil surveys including soil names, map unit, erodibility, permeability, depth, texture, and soil structure.
- Stormwater discharges, including the quality of any existing or proposed stormwater discharges from the site and known sources of pollutants and sediment loadings.
- Critical areas, buffers, and setbacks established by the local, state, and federal regulatory authorities.
- Water quality classification of on-site and adjacent waterbodies and identification of any on-site or adjacent waterbodies included on the Rhode Island 303(d) list of impaired waters.

- ***Potential Stormwater Impacts:*** Describe the project's potential for stormwater impacts affecting water quality, peak flow, and groundwater recharge. The elements that should be included in this section are:

  - Description of all potential pollution sources such as erosive soils, steep slopes, vehicle fueling, vehicle washing, etc.
  - Identification of the types of anticipated stormwater pollutants and the relative or calculated load of each pollutant
  - A summary of calculated pre- and post-development peak flows
  - A summary of calculated pre- and post-development groundwater recharge.

- ***Critical On-site Resources:*** Describe and identify the locations of on-site resources that could potentially be impacted by stormwater runoff. These resources may include:

  - Wells
  - Aquifers
  - Wetlands
  - Streams
  - Ponds
  - Public drinking water supplies.

- ***Critical Off-site Resources:*** Describe and identify the locations of off-site resources (e.g. typically downstream of the site) that could potentially be impacted by stormwater runoff. These resources may include:

  - Neighboring land uses
  - Wells
  - Aquifers
  - Wetlands
  - Streams
  - Ponds
  - Public drinking water supplies.

- ***Proposed Stormwater Management Practices:*** Describe the proposed stormwater management practices and why they were selected for the project. Stormwater management practices that should be described in this section are:
  - Source controls and pollution prevention
  - Alternative site planning and design
  - Stormwater treatment practices
  - Flood control and peak runoff attenuation management practices.

- ***Construction Schedule:*** Describe the anticipated construction schedule, including the construction sequence and any proposed phasing of the project.

9.6 Construction Erosion and Sedimentation Controls

The proposed Erosion and Sedimentation Control Plan should, at a minimum, demonstrate the methods and designs to be utilized during construction and stabilization of the site following completion of construction activity. All proposed erosion and sediment control measures must comply with the *Rhode Island Soil Erosion and Sediment Control Handbook,* (Rhode Island Department of Environmental Management, USDA Soil Conservation Service and Rhode Island State Soil Conservation Committee, 1989). Erosion and sediment control measures must be included on the plans with sufficient detail to facilitate review of the design by regulatory officials and proper construction.

9.7 Operation and Maintenance

Stormwater management plans should describe the procedures, including routine and non-routine maintenance, that are necessary to maintain treatment practices, including vegetation, in good and effective operating conditions. Chapter Eleven of this manual contains operation and maintenance guidelines and recommendations for individual stormwater treatment practices. Operation and maintenance elements that should be included in the stormwater management plan include:

- Detailed inspection and maintenance requirements/tasks
- Inspection and maintenance schedules
- Parties legally responsible for maintenance (name, address, and telephone number)
- Provisions for financing of operation and maintenance activities
- As-built plans of completed structures
- Letter of compliance from designer
- Post-construction documentation to demonstrate compliance with maintenance activities.

9.8 Other Required Permits

Approval of a stormwater management plan does not relieve a property owner of the need to obtain other permits or approvals from federal, state, and local regulatory agencies. The stormwater management plan should include evidence of acquisition of all applicable federal, state, and local permits or approvals such as copies of DEM permit registration certificates, local approval letters, etc.

Where appropriate, a grading or building permit may not be issued for any parcel or lot unless a stormwater management plan has been approved or waived. If requirements of federal, state, and local officials vary, the most stringent requirements should be followed.

9.9 Supporting Documents and Studies

Information used in the design of construction and post-construction stormwater controls for the overall site development must be included (or referenced, if appropriate) with reports, plans, or calculations to support the designer's results and conclusion. Pertinent information may include:

- Soil maps, borings/test pits.
- Infiltration test results.
- Groundwater impacts for proposed infiltration structures.
- Reports on wetlands and other surface waters (including available information such as Maximum Contaminant Levels [MCLs], Total Maximum Daily Loads [TMDLs], 303(d) or 305(b) impaired waters listings, etc.).
- Water quality impacts to receiving waters and biological/ecological studies.
- Flood study/calculations.

References

Chapter Ten – Stormwater Retrofits

10.1 Introduction

Existing development can be modified to incorporate source controls and structural stormwater treatment practices. Such modifications are commonly referred to as stormwater retrofits. This chapter describes opportunities and techniques for retrofitting existing, developed sites to improve or enhance water quality mitigation functions. This chapter also identifies the conditions for which stormwater retrofits are appropriate, as well as the potential benefits and effectiveness of stormwater retrofits.

10.2 Objectives and Benefits of Stormwater Retrofits

The objective of stormwater retrofitting is to remedy problems associated with and improve water quality mitigation functions of older, poorly designed, or poorly maintained stormwater management systems. In Rhode Island, prior to the 1970s, site drainage design did not require stormwater detention for controlling post-development peak flows. As a result, drainage, flooding, and erosion problems are common in many older developed areas of the state. Furthermore, a majority of the stormwater detention facilities throughout the state have been designed to control peak flows, without regard for water quality mitigation. Therefore, many existing stormwater detention basins provide only minimal water quality benefit.

Incorporating stormwater retrofits into existing developed sites or into redevelopment projects can reduce the adverse impacts of uncontrolled stormwater runoff. This can be accomplished through reduction in unnecessary impervious cover, incorporation of small-scale Low Impact Development (LID) management practices, and construction of new or improved structural stormwater treatment practices. One of the primary benefits of stormwater retrofits is the opportunity to combine stormwater quantity and quality controls. Stormwater retrofits can also remedy local nuisance conditions and maintenance problems in older areas, and improve the appearance of existing facilities through landscape amenities and additional vegetation.

10.3 When is Retrofitting Appropriate?

Site constraints commonly encountered in existing, developed areas can limit the type of stormwater retrofits that are possible for a site and their overall effectiveness. Retrofit of an existing stormwater management facility according to the design standards contained in Chapter Eleven of this manual may not be possible due to site-specific factors such as the location of existing utilities, buildings, wetlands, maintenance access, and adjacent land uses. Table 10.3-1 lists site-specific factors to consider in determining the appropriateness of stormwater retrofits for a particular site.

Table 10.3-1

Site Considerations for Determining the Appropriateness of Stormwater Retrofits

Factor	Consideration
Retrofit Purpose	What are the primary and secondary (if any) purposes of the retrofit project? Are the retrofits designed primarily for stormwater quantity control, quality control, or a combination of both?
Construction/Maintenance Access	Does the site have adequate construction and maintenance access and sufficient construction staging area? Are maintenance responsibilities for the retrofits clearly defined?
Subsurface Conditions	Are the subsurface conditions at the site (soil permeability and depth to groundwater/bedrock) consistent with the proposed retrofit regarding subsurface infiltration capacity and constructability?
Utilities	Do the locations of existing utilities present conflicts with the proposed retrofits or require relocation or design modifications?
Conflicting Land Uses	Are the retrofits compatible with adjacent land uses of nearby properties?
Wetlands, Sensitive Water Bodies, and Vegetation	How do the retrofits affect adjacent or downgradient wetlands, sensitive receiving waters, and vegetation? Do the retrofits minimize or mitigate impacts where possible?
Complementary Restoration Projects	Are there opportunities to combine stormwater retrofits with complementary projects such as stream stabilization, habitat restoration, or wetland restoration/mitigation?
Permits and Approvals	Which local, state, and federal regulatory agencies have jurisdiction over the proposed retrofit project, and can regulatory approvals be obtained for the retrofits?
Public Safety	Does the retrofit increase the risk to public health and safety?
Cost	What are the capital and long-term maintenance costs associated with the stormwater retrofits? Are the retrofits cost-effective in terms of anticipated benefits?

Source: Adapted from Claytor, Center for Watershed Protection, 2000.

Retrofitted facilities may not be as effective in reducing pollutant loads, for example, as newly designed and installed facilities. However, in most cases, some improvements in stormwater quantity and quality control are possible, especially if a new use is planned for an existing development or an existing storm drainage system is upgraded or expanded. Incorporation of a number of small-scale LID management practices or a treatment train approach may be necessary to achieve the desired level of effectiveness. It should also be recognized that stormwater quantity frequently creates the most severe impacts to receiving waters and wetlands as a result of channel erosion (Claytor, Center for Watershed

Protection, 2000). Therefore, stormwater quantity control functions that existing stormwater management facilities provide should not be significantly compromised in exchange for pollutant removal effectiveness.

10.4 Stormwater Retrofit Options

Stormwater retrofit options include many of the source control and stormwater treatment practices for new developments that are described in other chapters of this manual. Common stormwater retrofit applications for existing development and redevelopment projects include:

- Stormwater drainage system retrofits.
- Stormwater management facility retrofits.
- New stormwater controls at storm drain outfalls.
- New stormwater controls for road culverts and rights-of-way.
- In-stream practices in existing drainage channels.
- Parking lot stormwater retrofits.
- Wetland creation and restoration.

Examples of these stormwater retrofits are described in the following sections.

10.4.1 Stormwater Drainage Systems

Existing drainage systems can be modified to improve water quality mitigation and sediment removal functions. These retrofits alone typically provide limited benefits, but are most successful when used in conjunction with other source controls and stormwater treatment practices. Due to their very nature as an integral part of the stormwater collection and conveyance system and inherent solids trapping function, these retrofits typically have high maintenance requirements. Common examples of stormwater drainage system retrofits include:

- ***Deep Sump Catch Basins with Hoods:*** Older catch basins without sumps can be replaced with catch basins having four to six-foot deep sumps. Sumps provide storage volume for coarse sediments, provided that accumulated sediment is removed on a regular basis. Hooded outlets, which are covers over the catch basin outlets that extend below the standing water, can also be used to trap litter and other floatable materials. A recent study conducted in New York City demonstrated that catch basins equipped with hoods increase the capture of floatables by 70 to 80 percent over catch basins without hoods and greatly extend the cleaning interval without degraded capture performance (Pitt, 1999 in NRDC, 1999).

- ***Catch Basin Inserts and Storm Drain Structures:*** As discussed in Chapter Six, a number of manufactured devices have been developed that can be inserted into storm drains or catch basins to capture sediment and other pollutants directly beneath the grate. These products typically utilize filter media or vortex action for removal of solids from incoming stormwater runoff. These devices are ideally suited for developed sites since they fit inside of or replace existing catch basins, or are installed beneath existing parking lots with minimal or no additional space requirements.

10.4.2 Stormwater Management Facilities

Existing stormwater management facilities originally designed for flood control can be modified or reconfigured for water quality mitigation purposes or increased hydrologic benefit. Older detention facilities offer the greatest opportunity for this type of retrofit. Traditional dry detention basins can be modified to become extended detention basins, wet ponds, or stormwater wetlands for enhanced pollutant removal. This is one of the most common and easily implemented retrofits since it typically requires little or no additional land area, utilizes an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources (Claytor, Center for Watershed Protection, 2000).

Some common modifications to existing detention basins for improved water quality mitigation are listed below:

- Excavate the basin bottom to create more permanent pool storage.
- Eliminate low-flow bypasses.
- Raise the basin embankment to obtain additional storage for extended detention.
- Incorporate stilling basins at inlets and outlets and sediment forebays at basin inlets.
- Modify the outfall structure to create a two-stage release to better control small storms while not significantly compromising flood control detention for large storms.
- Regrade the basin bottom to create a wetland area near the basin outlet or revegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics.
- Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms, or micro-pond topography to increase residence time of water in the pond and improve settling of solids.
- Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions.
- Replace paved low-flow channels with meandering vegetated swales.
- Create a low maintenance “no-mow” wildflower ecosystem in the drier portions of the basin.

Stormwater detention basin retrofits should include an evaluation of the hydraulic characteristics and storage capacity of the basin to determine whether available storage exists for additional water quality treatment. A typical retrofit of an existing detention basin is shown in Figure 10.4.2-a.

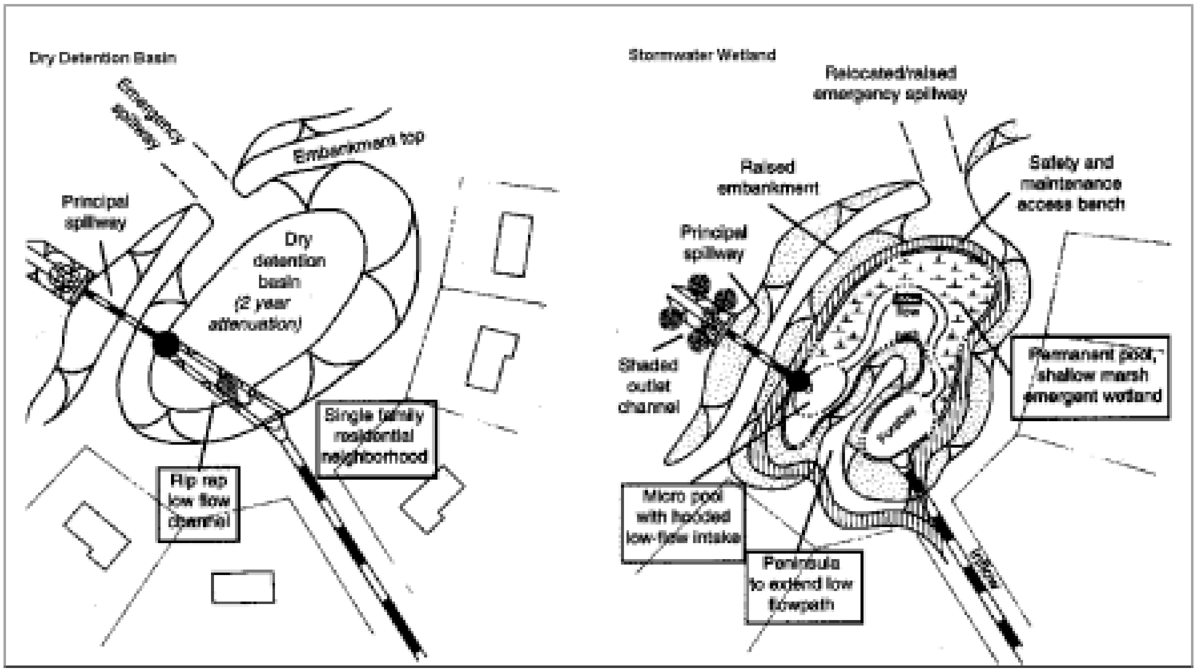

Figure 10.4.2-a Stormwater retrofit of an existing dry detention basin. Source: Adapted from Claytor, Center for Watershed Protection, 2000

10.4.3 Storm Drain Outfalls

New stormwater treatment practices can be constructed at the outfalls of existing drainage systems. The new stormwater treatment practices are commonly designed as off-line devices to treat the water quality volume and bypass larger storms. Water quality swales, bioretention, sand filters, constructed wetlands, and wet ponds are commonly used for this type of retrofit, although most stormwater treatment practices can be used for this type of retrofit given enough space for construction and maintenance. Figure 10.4.3-a shows a

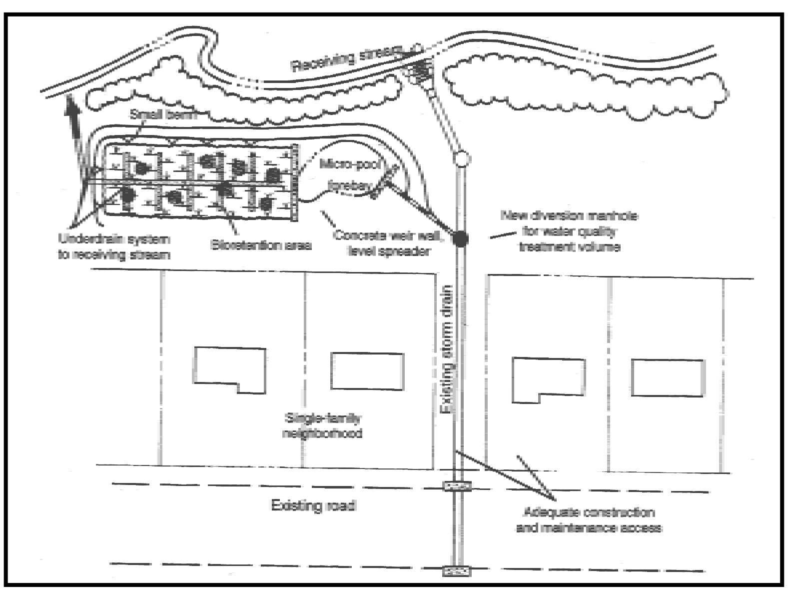

Figure 10.4.3-a Retrofit using bioretention. Source: Claytor, Center for Watershed Protection, 2000

schematic of an existing outfall retrofitted with an off-line bioretention area. Manufactured, underground treatment devices such as those described in Chapter Six are also commonly installed as off-line retrofits at or upgradient of stormwater outfalls. Velocity dissipation devices such as plunge pools and level spreaders can also be incorporated into the retrofit design.

10.4.4 Highway Rights-of-Way

Open spaces associated with highway rights-of-way such as medians, shoulders, and cloverleaf areas also present opportunities to incorporate new stormwater treatment practices. Common treatment practices used in these types of retrofits include vegetated swales, bioretention, constructed wetlands, and extended detention ponds. Traffic, safety, and maintenance access are important considerations for determining appropriate locations for highway right-of-way retrofits.

10.4.5 Parking Lots

Parking lots can be ideal candidates for a wide range of stormwater retrofits. Potentially applicable retrofits include site-planning techniques and small-scale management measures to reduce impervious coverage and promote increased infiltration (chapter 4), as well as a variety of larger, end-of-pipe treatment practices (Figure 10.4.5-a).

Figure 10.4.5-a End-of-pipe retrofit under construction at Zambarano Hospital in Rhode Island

Redevelopment of older commercial properties, which were often designed with oversized parking lots and almost 100 percent impervious coverage, is one of the most common and environmentally beneficial opportunities for parking lot stormwater retrofits.

Alternative site design and LID management practices are well-suited to existing developed areas because most of these practices use a small amount of land and are easily integrated into existing parking areas. Examples of these parking lot stormwater retrofits include:

- ***Incorporating Bioretention Into Parking Lot Islands and Landscaping:*** Parking lot islands, landscaped areas, and tree planter boxes can be converted into functional bioretention areas and rain gardens to reduce and treat stormwater runoff.

- ***Removing Curbing and Adding Slotted Curb Stops:*** Curbs along the edge of parking lots can sometimes be removed or slotted to re-route runoff to vegetated areas, buffer strips, or bioretention facilities. The capacity of existing swales may need to be evaluated and expanded, where necessary, as part of this retrofit option.

- ***Infiltrating Clean Roof Runoff From Buildings:*** In some instances, building roof drains connected to the stormwater drainage system can be disconnected and re-directed to vegetated areas, buffer strips, bioretention facilities, or infiltration structures (dry wells or infiltration trenches).

- ***Incorporating New Treatment Practices at the Edge of Parking Lots:*** New stormwater treatment practices such as bioretention, sand filters, and constructed wetlands can often be incorporated at the edge of large parking lots.

- ***Use of Permeable Paving Materials:*** Existing impermeable pavement in overflow parking or other low-traffic areas can sometimes be replaced with alternative, permeable materials such as modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids. Site-specific factors including traffic volumes, soil permeability, maintenance, sediment loads, and land use must be carefully considered for the successful application of permeable paving materials for new development or retrofit applications.

These approaches are also discussed in chapter 4, which includes diagrams and pictures of the practices.

10.4.6 In-Stream Practices in Drainage Channels

Existing (man-made) channelized streams and drainage conveyances such as grass channels can be modified to reduce flow velocities and enhance pollutant removal. Weir walls or riprap check dams placed across a channel create opportunities for ponding, infiltration, and establishment of wetland vegetation upstream of the retrofit (Claytor, Center for Watershed Protection, 2000). In-stream retrofit practices include stream bank stabilization of eroded areas and placement of habitat improvement structures (i.e., flow deflectors, boulders, pools/riffles, and low-flow channels) in impacted natural streams and along stream banks. In-stream retrofits may require evaluation of potential flooding and floodplain impacts resulting from altered channel conveyance, as well as local, state, or federal approval for work in wetlands and watercourses. More comprehensive urban stream and stream corridor restoration practices are beyond the scope of this manual. Additional sources of information on stream restoration practices are included at the end of this chapter.

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